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FABRICATION AND STUDY OF HARDNESS BEHAVIOUR ON GAMMA IRRADIATED ULTRA-HIGH MOLECULAR WEIGHT POLYETHYLENE (UHMWPE) PLATE

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ABSTRACT

Over the decades, there has been an enormous development in the field of polymers, especially in areas of Ultra-High Molecular Weight Polyethylene. Ultra High Molecular Weight (UHMWPE) Polyethylene materials have exceptional properties like high impact resistance, durability and high thermal conductivity. It finds its application in conveyor lines, wear strips, Bearings, gears, pistons, valves, marine equipment. But very little research has been done in the characterization study of Gamma irradiated UHMWPE and also the effect of different melt temperature on the uniqueness of UHMWPE seems to be an interesting thing. In this work, we have fabricated UHMWPE plates irradiated with Gamma rays using injection molding with different injection parameters like injection Velocity, melt temperature and compaction Time. The hardness behavior of this fabricated gamma irradiated Ultra-High Molecular Weight Polyethylene was analyzed.

***KEYWORDS:** UHMWPE, Gamma rays, Injection Molding, Spectra, Injection Velocity, Melt Temperature & Compaction Time*

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Original Article

INTRODUCTION

A polymer is a huge molecule composed of repeating structural units. The subunits of polymer are usually linked by covalent chemical bonds. Even though the term polymer is every so often taken to refer to plastics, it actually encompasses a large group of natural and synthetic materials with a wide variety of properties. It was found that the ultimate strength, yield strength, elongation at break, and resistance to fatigue of vitamin E–stabilized UHMWPE were noticeably superior than that of 100 kGy–irradiated and melted UHMWPE, and were unaltered by accelerated aging [1].

The astonishing ranges of properties of polymeric materials play a vital and ubiquitous role in everyday life. This role ranges from well-known synthetic plastics and elastomers to natural biopolymers such as nucleic acids and proteins that are essential for life. The Natural polymer materials such as amber, and natural rubber have been used for many decades. A range of other natural polymers are present, such as cellulose, which is the main ingredient of wood and paper. The list of synthetic polymers includes synthetic rubber, Bakelite, neoprene, nylon,

PVC, polystyrene, polyethylene, polypropylene, polyacrylonitrile, PVB, silicone, and many more. Among the synthetic polymers, Spectra is polymer made from ultra high molecular weight polyethylene (UHMWPE), which is a outstandingly durable and rugged material with higher melting temperature than standard polyethylene (150ºC/300ºF) [8].

Classification

Polyethylene can be classified into various categories based generally on its density and branching. The mechanical properties of Polyethylene depend drastically on variables like the type and extent of branching, the crystal structure and the molecular weight. The following are the various types of polyethylene :

- Ultra high molecular weight polyethylene (UHMWPE)
- Ultra low molecular weight polyethylene (ULMWPE or PE-WAX)
- High molecular weight polyethylene (HMWPE)
- High density polyethylene (HDPE)
- High density cross-linked polyethylene (HDXLPE)
- Cross-linked polyethylene (PEX or XLPE)
- Medium density polyethylene (MDPE)
- Linear low density polyethylene (LLDPE)

PROBLEM IDENTIFICATION

It has been observed from the literature review, very few studies have been done in the characterization study of Gamma irradiated UHMWPE. Also the effect of different melts temperature on the characteristics of UHMWPE also seems to be a novalic.

Hence, in this present study, it is proposed to prepare the Gamma irradiated UHMWPE specimens with different melt temperature and its hardness behavior has been investigated.

Proposed Methodology

In this work, the following methodology was carried out. The irradiated UHMWPE plate was fabricated.

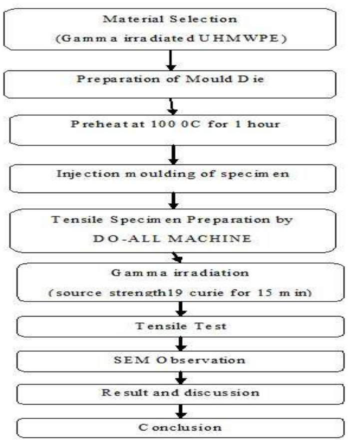


Figure 1: Flow Chart Proposed Methodology

SPECIMEN PREPARATION

Injection molding is a process of molding in which the molding material, is usually preheated, is placed first in an open and heated mold cavity. Injection molding is a high-volume, high-pressure method which is suitable for molding multifaceted, high-strength fiberglass reinforcements. Superior composite thermoplastics can also be Injection molded with unidirectional tapes, woven fabrics, arbitrarily oriented fiber mat or chopped strand. The benefit of Injection molding is its ability to mold large, fairly intricate parts.

Work Material

Injection grade UHMWPE powders were obtained from SPECTRA PLASTICS, Coimbatore, Tamilnadu. The density of the UHMWPE was 927 - 944 Kg/m3, in order to insure that all observed and absorbed moisture were removed and to prevent void formation, the UHMWPE were dried at 1000C under vacuum for 2hrs before processing. This resulted in a moisture content of 1- 2% in the products scaled container.

The dried UHMWPE powders were fed into the Injection molding machine through hopper. The temperature was set a range of 260^0C to 300^0C to melt the powder. The powders are melted and transfer into the die cavity of injection moulding machine. A mild steel mold, die has been used for preparations of the tensile test specimens. The die was manufactured in M. R. Engineering Works, Ekkattuthangal, and Chennai, India. The mold die cavity was machined with the help of Computer Numerical Control (CNC) machine. Fig.3.10 shows the dimensions of tensile specimen are which 150mm length, 25mm grip width, 90mm for distance between shoulders, 80mm for gauge length. The width of reduced section is 10mm while the width of 'V' notch at 45^0 angles is 2mm. The die cavity is preheated in order to remove the moisture content. The die cavity is properly fastened once the molten powders are fed.

Table 1: Specification of Do all machine

Model No: DBW-1	DBW-1
Voltage	220 V
Cycle	50 Hz
Speed	0 to 1600 feed per minute
Amperage	30 A

(a)

(b)

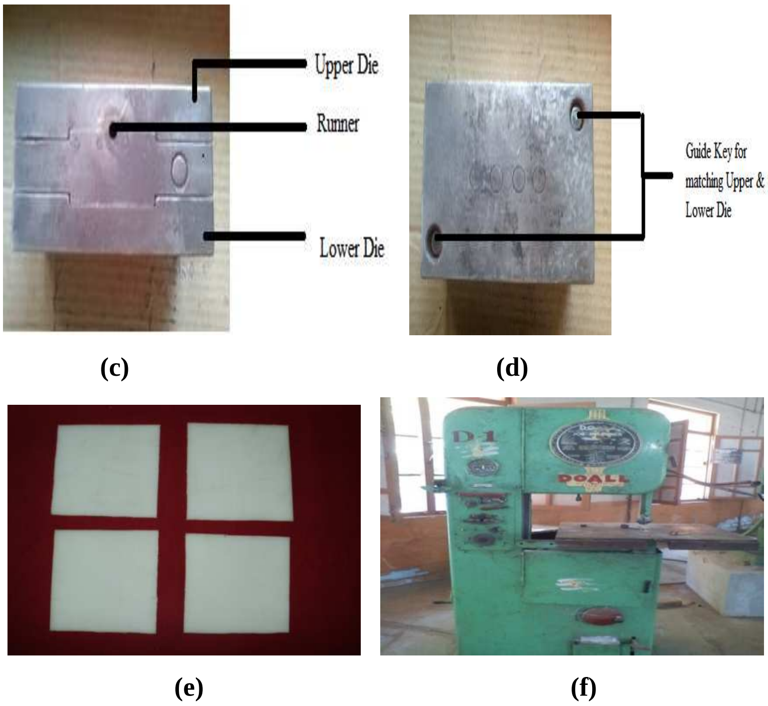


Figure 2: (a) Injection Moulding Machine, (b) Feeding of UHMWPE, (c) Die from Top View, (d) Die from Side View, (e) UHMWPE Plates Prepared for Hardness Test, and (f) Do-All Machine used to Prepared the Specimen

Different injection parameters were selected for this study and they are tabulated in table given below.

Table 2: Different Injection Parameters

Sl. No	Injection Velocity(Iv) mm/min	Melt Temperature (MT)^0 C	Compaction Time (CT) sec
1	75	260	30
2	125	280	60
3	175	300	90

Injection of Raw Material

Proper Injection of raw material is essential for the uniformity of the finished product. The entire specimens were prepared by Injection molding machine. After preheating, the powder UHMWPE is fed into the heater of Injection molding machine. The heater should maintain the temperature range between 260^{0}C and 300^{0}C to easy flow of raw UHMWPE into the mould die.

Irradiation Process

After the preparing of UHMWPE tensile test specimens were subjected to irradiate with gamma source (Iridium 192). The strength of the source is 19 curie, source to film distance (SFD) of 20 inches, with a time of 15 minutes, which is shown in figure 3. The irradiating process was done in Industrial X Ray Co, Ekkaduthangal, and Chennai. Radiation cross-linking and heat treatment of UHMWPE has proven to be an important advance that resulted in the innovation of a numeral of highly cross-linked UHMWPEs with enhanced wear resistance [2-7].

Figure 3: Gamma source

HARDNESS BEHAVIOR

After gamma irradiation, UHMWPE specimens were subjected to micro hardness test were conducted at room temperature at a constant load of 10N with time of 15 sec. The micro hardness tester is available in the Department of Manufacturing Engineering in Annamalai University. The specification of the micro hardness tester is shown in table no.2. Figure.3.15 and Figure.3.16 shows the schematic representation of the Micro hardness tester.

Table 3: Specification of Micro Hardness Tester

Make:	HMV- Japan
Model:	HMV-2T
Magnification:	400X
Time:	15sec

Micro hardness is considered as one of the important properties of materials, which acts as an indicator for the mechanical properties of polymers. The micro hardness for γ- UHMWPE with different melt temperature are shown in Table.4. It is observed that the micro hardness is a maximum of 10.82 Hv for γ- irradiated when the melt temperature was maintained at 280^{O} C. The minimum hardness is obtained 6.24 Hv for melt temperature of 260^{O}C.

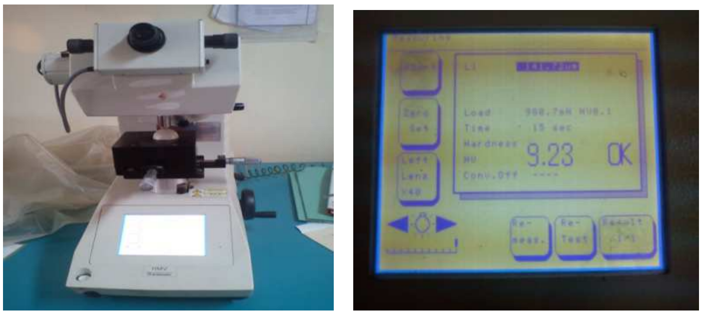


Figure 4: Micro Hardness Tester

RESULT AND DISCUSSIONS

Melt Temperature Vs Hardness

It has been observed from the above graph that at 260˚, the hardness of the material increases as the speed of the ram increases due to higher melting point and density of the UHMWPE material. The percentage of elongation decreases, which may also result into the break of the material due to the compaction time of the material of the specimen and lower ultimate tensile stress. This also led to rough surface finish.

At 280˚ C, the hardness first increases and then decreases and again increases as the velocity of ram increases due to the higher value of ultimate stress. This tends to the better surface finish. The result in better hardness at this

temperature.

At 300˚ C, the hardness of the UHMWPE material decreases as the velocity of the ram increases due to the higher ultimate tensile stress and higher viscosity at this temperature. This leads to rough surface finish.

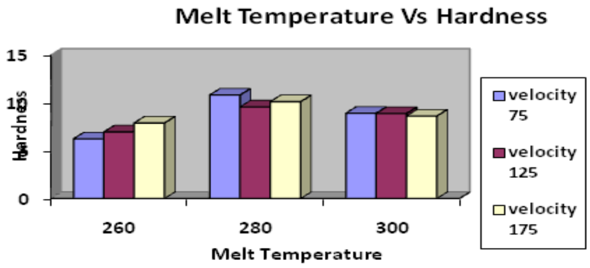


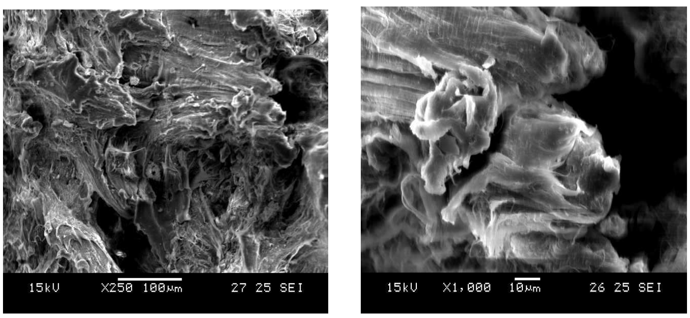
Figure 5: Melt Temperature Vs Hardness

Table 4: Result for Testing Specimens

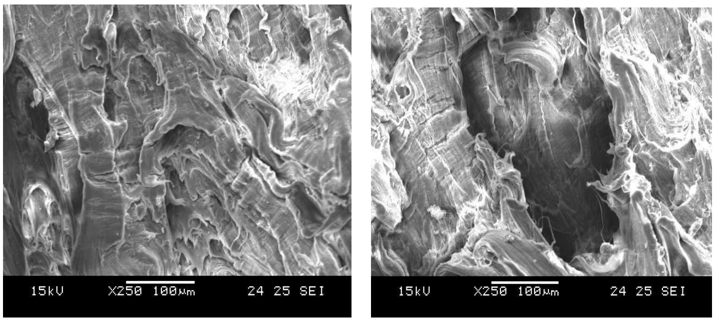
Injection Velocity mm/min	Melt Temp °C	Compaction Time, Sec	Hardness, Hv
75	260	30	6.24
75	280	60	10.82
75	300	90	8.92
125	260	60	6.96
125	280	90	9.58
125	300	30	8.89
175	260	90	7.89
175	280	30	10.12
175	300	60	8.62

SEM OBSERVATION

In Figure 6 (a) and 6 (b), at melt temperature 260^{0}C and 300^{0}C, it can be seen that gamma irradiated specimen is having short elongation. The ductility of the material was poor, because of poor bonding strength and density.



(a) (b)



(c) **(d)**

Figure 6: SEM Images

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